Restructuring RELAP5-3D

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Outline

- Purpose
- FORTRAN 90 programming
- Conversion Methodology
- Measurements

Purpose

- Convert interwoven logic flow paths (spaghetti) to structured blocks of coding
- Improvements (according to computer industry) gained by structuring the code.
  - Easier to read and understand
  - Less time required for code development
  - Reduced debugging time
  - Reduced cost for maintenance
- These will lead to greater robustness

Definition: Structured Programming

– ***From General Services Administration, Federal Standard 1037C (Telecom Glossary 2000)***

- **A <u>technique</u> for organizing and coding computer programs in which a <u>hierarchy of modules</u> is used, each having a <u>single entry</u> and a <u>single exit point</u>, and in which *<u>control</u>* is passed <u>downward</u> through the structure with <u>no unconditional branches</u> to higher levels of the structure.**

  There are three types of flow *<u>control</u>*:
  - **Sequential**
  - **Test (*if* and *case*)**
  - **Iteration (*loop*)**

Definition of a "Block of Code"

- A *module* or *block of code* is a group of consecutive lines of code and/or smaller blocks that have:
  - A *single entry point* at the top
  - A *single exit point*
  - *Execution* or *control* passes downward through consecutive statements or blocks
- Examples

Structured

```
Read (IN, FMT) A
B = A/3.14159265
Write (OUT) B
```

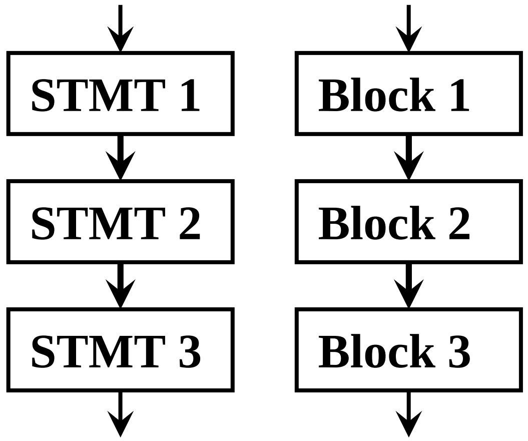
Unstructured

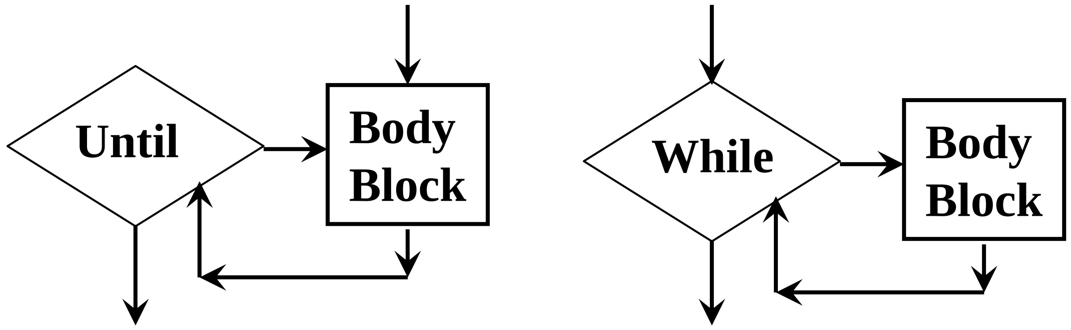
```
      Read (IN, FMT) A
10    B = A/3.14159265
      Write (OUT) B
```

- *The second example has more than one entry point.*

Flowcharts of Structured Blocks

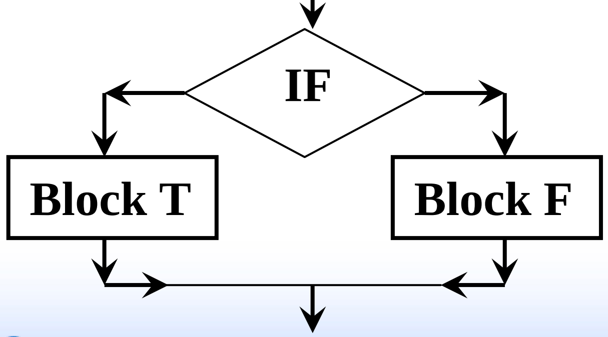
- **Sequential** **Iteration / Loop**

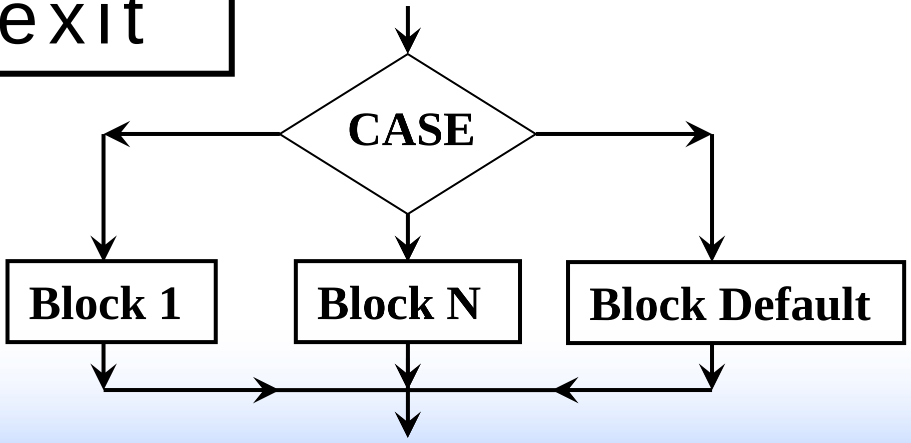




One entry
One exit

- **If / Case**





Structured Programming

- Essentially, there are:
  - No GO TO statements (multiple entry)
  - No multiple returns (multiple exit)
- For loops, special structured GO TO statements:
  - EXIT – leave loop immediately when condition occurs and resume execution with statement after end-of-loop
  - CYCLE – leave iteration of loop immediately and resume execution with loop’s test statement

FOR_STRUCT

- FOR_STRUCT is a commercial software package for structuring unstructured code
  - Applies to FORTRAN IV, FORTRAN 66, and FORTRAN 77
    - Does not work on FORTRAN 90 code.
- Reformats code it restructures, for example:
  - Uniform spacing conventions
  - Uniform indentation
  - Resequencing of line labels

FOR_STRUCT Restructuring

REPLACES

if (.not. condition) go to

```
      if (.not.condition) go to 10
      Block 1
      go to 20
10    Block 2
20    continue
```

Arithmetic IF

Computed GO TO

WITH

if (condition) then

```
if (condition) then
  Block 1
else
  Block 2
endif
```

IF-THEN-ELSE-ELSEIF

CASE

FOR_STRUCT Restructuring

REPLACES	**WITH**
• Do-loop continue statements	end do statement
• Jump to end of iteration	cycle statement
• Jump out of loop	exit statement
• Backwards go to	do while statement *
• Multiple returns in a subroutine	case statement and a single return

*** Only if it is an actual loop.**

FOR_STRUCT Limitations

- Some coding is so complex that FOR_STRUCT only partially restructures it.
- FOR_STRUCT cannot process pre-compiler directives.
  - #IFDEF and #INCLUDE
- FOR_STRUCT cannot process FORTRAN 90 code.

Overcoming FOR_STRUCT limits

- **Partially restructuring**
  - **Applying FOR_STRUCT to its own output further restructures complex code.**
  - **We used 3 iterations.**
- **Pre-compiler directives**
  - **After applying pre-compiler, any coding that was removed is not restructured.**
  - **Restructure file several times with different flags active.**
  - **Recombine carefully.**

Methodology: Complexity Control

- Files vary in complexity with:
  - Size of file
  - The number of different IFDEFS
  - The number of IFDEF branches
  - Nesting of IFDEFS
- Sorted files according number of IFDEFS and then according to size.
  - Process files from least complexity to greatest
  - Develop means to overcome each difficulty as it occurs.

Methodology: Work in stages

- Stage 1 – Prepare file
  - Prepare to apply CPP and FOR_STRUCT.
- Stage 2 – Process file
  - Apply CPP and FOR_STRUCT
- Stage 3 – Post-processing file
  - Essentially, undo the preparations

Stage 1: Preparing a file

- Replace F90 derived-type variables with dummy variables.
- Associate an index number with each IFDEF.
- Make "commented copies" of IFDEFS and INCLUDES.
- Append DEFINE heading(s) to file, usually creating multiple files.
  - Combinations of DEFINEs depend on:
    - Nesting
    - Mutually exclusive options

Preparing a file: Example

Original File

```
      ix = vlm(mi)%vctrls
#ifndef int32
      iip = ishft(is23(ix),-30)
#endif
c  Set indexes in tables
  11    if (s(ix) .ge. a(iip)) go to 10
        iip = iip - 1
        go to 11
  10    continue
```

$\rightarrow$

Prepared File

```
      ix = dummy1avctrls
Converted #ifndef 4.0.0.0 i@nt32
#ifndef int32
      iip = ishft(is23(ix),-30)
#endif
C~LIT_ON
Converted #endif 4.0.0.0
C~LIT_OFF
c  Set indexes in tables
  11    if (s(ix) .ge. a(iip)) go to 10
        iip = iip - 1
        go to 11
  10    continue
```

Stage 2: Processing a file

- Preprocess the file(s) with CPP
  - Expands INCLUDES
  - Eliminates some conditional code
- Run FOR_STRUCT iteratively on each file.
- Troubleshoot errors by manually changing the input or output file.
  - Usually involves moving an ENDIF into or out of an IFDEF block

Processing a file: Example

After CPP

```
          ix = dummy1avctrls
Converted #ifndef 4.0.0.0 i@nt32
C~LIT_ON
Converted #endif 4.0.0.0
C~LIT_OFF
c  Set indexes in tables
   11     if (s(ix) .ge. a(iip)) go to 10
          iip = iip - 1
          go to 11
   10     continue
```

After FOR_STRUCT

```
      ix = dummy1vctrls
Converted #ifndef 4.0.0.0 i@nt32
C~LIT_ON
Converted #endif 4.0.0.0
C~LIT_OFF
C  Set indexes in tables
        do while (s(ix).lt.a(iip))
          iip = iip - 1
        end do
```

Note, the code protected with "#ifndef int32" was eliminated by CPP.

Methodology: Post Processing

- Substitute F90 variables for dummy variables.
- Combine files into one complete file.
  - Use IFDEF indexes to match blocks of code.
  - Verify the number of IFDEFs did not change.
- Uncomment the commented copies of IFDEFS and INCLUDES.
- Delete the included files.
- Fix the undesirable formatting details that FOR_STRUCT predictably produces.
- Run small test set; ensure output remains same.

Post Processing a file: Example

After FOR_STRUCT

```
      ix = dummmy1vctrls
Converted #ifndef 4.0.0.0 i@nt32
C~LIT_ON
Converted #endif 4.0.0.0
C~LIT_OFF
C  Set indexes in tables
       do while (s(ix).lt.a(iip))
         iip = iip - 1
       end do
```

After Post Processing

```
      ix = vlm(mi)%vctrls
#ifndef int32
      iip = ishft(is23(ix),-30)
#endif
c  Set indexes tables
      do while (s(ix).lt.a(iip))
        iip = iip - 1
      end do
```

Results

- 443 files in the RELAP subdirectory restructured.
  - 53 files need no restructuring.
- For the 443 restructured files:
  - Avg # GOTOs/subroutine
    - Before: 10.6,   After: 5.4
  - Max # GOTOs in any subroutine
    - Before: 213,   After: 146
  - Max # labels in any subroutine
    - Before: 210,   After: 48